

Some Applications of Remote Sensing in Atmospheric Monitoring Programs

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Since air masses move in unconfined spaces, pollutants introduced into the air in one region are absorbed into the global circulation pattern, thereby affecting other regions. Pollution control strategies must recognize such effects and coordinated efforts are necessary. The unilateral ban on use of DDT in the United States offers a good example. If Mexico does not follow suit and continues to use large amounts of DDT for pest control, it is quite likely that the persistent chemical will find its way into many areas of the United States. This could be accomplished by the carryover of aerosols from aerial spraying, fine particulate matter and even birds (ref. 1); a good portion of our bird population migrates south each year where these migrants could easily absorb DDT.

Lead aerosol is a common air contaminant in urban areas and available data indicate that combustion of leaded gasoline is the major source of airborne lead in urban areas (ref. 2). One extensive study indicates that the atmosphere of the northern hemisphere contains about 1000 times more lead than the southern hemisphere as a result of man's contribution. The study also showed through geochemical measurements of sea water, sediments, and snow from remote areas that the level of lead in the environment is steadily increasing (refs. 3 and 4). Lead moves into other phases of environment especially through the scrubbing action of rain.

Recently mercury contamination has been observed in some of the northern lakes of the United States. There are virtually no industries in the catchment area of these lakes and one plausible explanation is that mercury also moves through the air medium. Eventually it seems to enter the aquatic environment.

The aforesaid emphasizes the need for a broad view in air-resources management. Remote sensing technology, although in an embryonic stage, may provide bases for extending our horizon. Present techniques of air quality measurement are generally dependent on Earth-bound sensors and reflect emphasis on local or regional management. One example of the regional approach is the program of the Department of Natural Resources and Environmental Control in New Castle County, Delaware. The 11-county Philadelphia Metropolitan Region encompasses New Castle whose population in 1970 was estimated at 386 000 (fig. 1). The population density of the northern half of the county (where most of the people live) is approximately 1460 per square mile. On a state-wide basis the population density is only 271 per square mile. Consequently our major air pollution problems are in northern New Castle County.

The air quality of New Castle County is determined by using a network of four primary stations and ten secondary stations (fig. 2). The primary stations are housed in self-contained trailers having internal dimensions of 16-foot length, 8-foot width, and 7-foot height. The instrumentation in the trailers is manufactured by various companies such as Technicon, Beckman, and Mine Safety Appliances. The entire monitoring system was supplied by Litton under a turnkey contract. Each of the primary stations (table 1) has the capability of continuously measuring the following air-quality indicators:

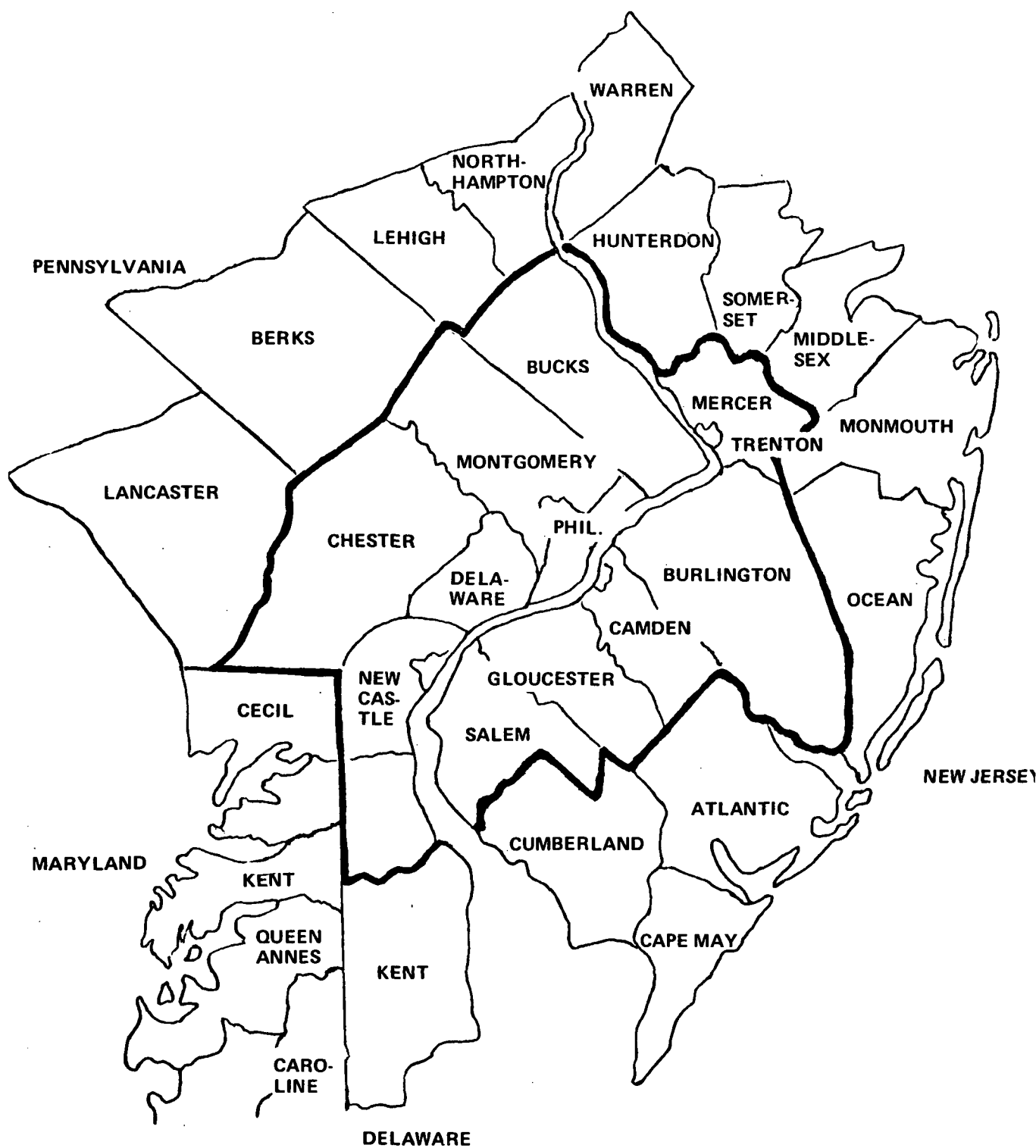


Figure 1.—Metropolitan Philadelphia air-quality control region.

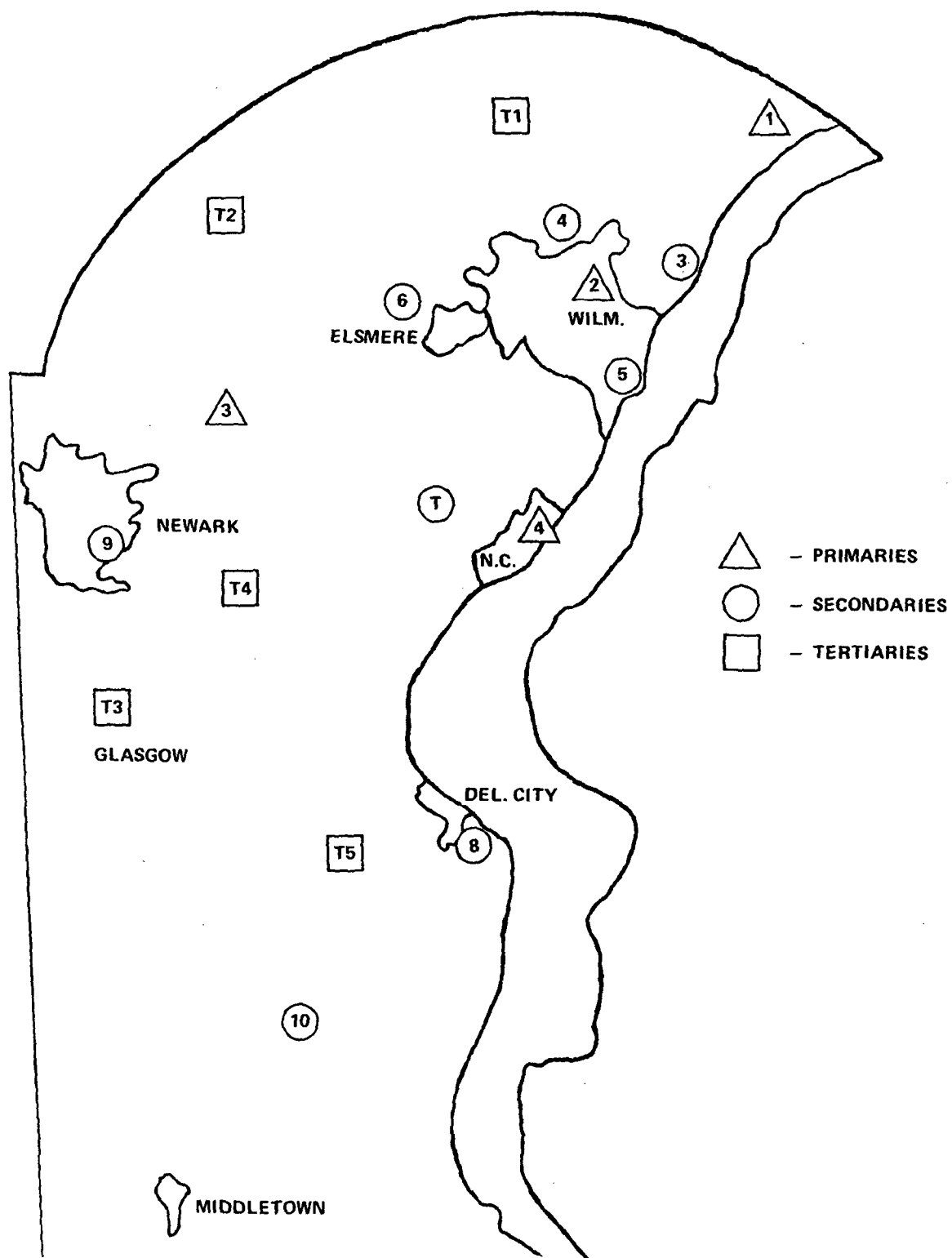


Figure 2.--New Castle County air-quality monitoring network.

Wind direction
Wind speed
Sulfur dioxide
Total oxidants
Nitrogen oxides

Total hydrocarbons
Carbon monoxide
Ozone
Particulate matter

As a backup for the primary system a series of ten secondary stations are also operated in New Castle County area. These stations have the capability of measuring sulfur dioxide and particulate matter on a continuous basis, and sulfation rate and dustfall on an integrated basis (table 2).

The signals from each of the sensors are electronically isolated, conditioned, and multiplexed. Each remote station is scanned every three minutes from a central data acquisition unit. The scanning cycle initiates a sequential transfer of data from the remote to the central station over leased, low grade telephone lines. The analog signals from the multiplexer are converted into digital information prior to transmission (figs. 3 and 4). A mini-computer in the data acquisition center maintains 15-minute, 1-hour, 6-hour, and 24-hour moving averages for each air-quality indicator at each of the four stations. These values are always available on hard copy. The 15-minute average is recorded on magnetic tape for storage and future processing. The tape is periodically shifted to the data processing center at Dover for statistical analysis.

The total cost of this system is approximately \$250 000. The real-time operation of this system offers quite a challenge in spite of sophisticated design of electronic components and instrumentation. There is still no substitute for frequent routine maintenance and calibration.

The data generated by the primary and secondary network offers a good measure of the general air quality in northern New Castle County. Figure 5 indicates the sulfur dioxide isopleths. The highest isopleths indicate areas of major industrial activity, including power production. The isopleths for suspended particulates are shown in figure 6. A hot spot is indicated in the Wilmington Marine Terminal area where there are several industrial emissions. Since New Castle County is bordered by the vast Philadelphia Metropolitan Region, the emissions from that area have a definite and deleterious interaction on local air quality in Delaware. This is shown in figure 7. The reduction of sulfur dioxide emissions in that region north of the state will materially improve the air quality within the State of Delaware.

An extensive survey of all emissions from New Castle County was conducted and the inventory yields information on the principal sources affecting air quality. Table 3 shows the contribution of sulfur dioxide emissions from various sources. Power generation, industrial processes, and industrial fuel burning account for almost 98 percent of the total emission into the atmosphere. The contribution of particulate emissions from various sources shown in table 4 indicates that power generation, industrial processes and fuel burning, again, account for almost 95 percent of the total emissions.

Although the initial emphasis is on the reduction of sulfur dioxide and particulates, we are concerned about other air pollutants such as carbon monoxide, nitrogen oxides, total oxidants, and heavy metals. In studies conducted by the University of Delaware Agricultural Department (ref. 5), oxidant damage to tobacco plants has been observed in Sussex County. This county with an area of 1000 square miles and an estimated population of 79 000 is quite unlikely to have high oxidant levels. However it is inferred that the oxidants may be carried over from the Washington-Baltimore metropolitan area into Sussex County through the general pattern of air circulation. Additional measurements are certainly needed to prove this cause and effect relationship. This observation further reinforces the comment made earlier on the movement of air masses from one region to another.

One recent example of the damage by air pollution is of interest in this context. Approximately two years ago, the Diamond Shamrock Chemical Corporation, which manufactures chlorine at Delaware City, found a leak in the system through which chlorine gas had escaped. A farmer nearby claimed damages to his standing crop of corn and demanded compensation. Inspection at the ground level indicated that such damage did occur and he was compensated by the company. If airborne sensing capabilities were available at that time, it would have been possible to precisely assess the damage caused in the entire area, including the corn crop. This is another illustration of the need for wide area coverage by airborne or other remote sensing devices.

Yates (ref. 6) suggests a satellite covering the entire globe once every 12 hours in a polar orbit. He claims that it can

TABLE 1.—Operational Characteristics of
Primary Air-Quality Monitoring Network

LOCATION:

In specially designed, 8 X 16-foot trailers with environmental controls.

DATA GENERATED:

- (a) Settleable solids—Dustfall buckets
- (b) Sulfation rate—Lead candles
- (c) Particle count—Sticky paper
- (d) Suspended particulates—Hi-vol sampler
- (e) Sulfur dioxide—West-Gaeke procedure, Technicon, continuous
- (f) Nitrogen dioxide—Saltzman procedure, Beckman, continuous
- (g) Ozone—Mast, continuous
- (h) Total Oxidants—Neutral potassium iodide procedure, Beckman, continuous
- (i) Total hydrocarbons—Flame ionization, MSA, continuous
- (j) Carbon monoxide—Infrared detector, MSA, continuous
- (k) Soiling index—Reflectance units, RAC, continuous
- (l) Wind speed—Litton Systems, continuous
- (m) Wind direction—Litton Systems, continuous

DATA REDUCTION:

- (a) Continuous data—15-minute averages output on hard copy and stored on magnetic tape for automatic data processing.
 - (b) Manual data—transferred to punch cards for automatic data processing.
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TABLE 2.—Operational Characteristics of
Secondary Air-Quality Monitoring Network

LOCATION:

In specially designed structures, either portable trailers or prefabricated wooden structures. Structures are 7 X 10 feet with controlled environment.

DATA GENERATED:

- (a) Settleable solids—Dustfall buckets
- (b) Sulfation rate—Lead candles
- (c) Particle count—Sticky paper
- (d) Suspended particulates—Hi-vol sampler
- (e) Soiling index—AISI tape sampler
- (f) Sulfur dioxide—Conductivity method, 30-minute averages
- (g) Gas sampler—24-hour average of five selected gases

DATA REDUCTION:

Manually transferred to punch cards, automatic preparation of statistical reports.

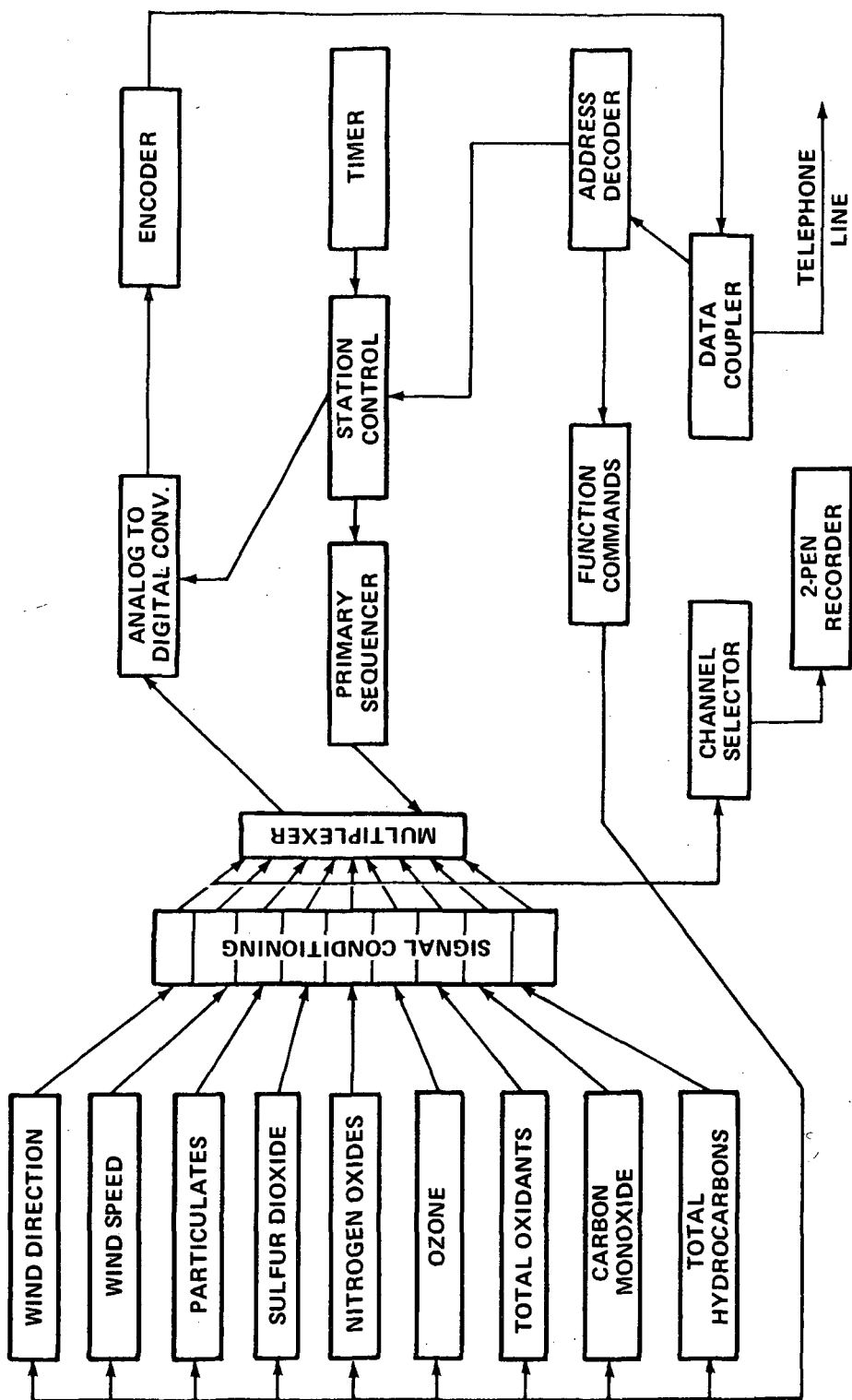


Figure 3.—Delaware primary monitoring station.

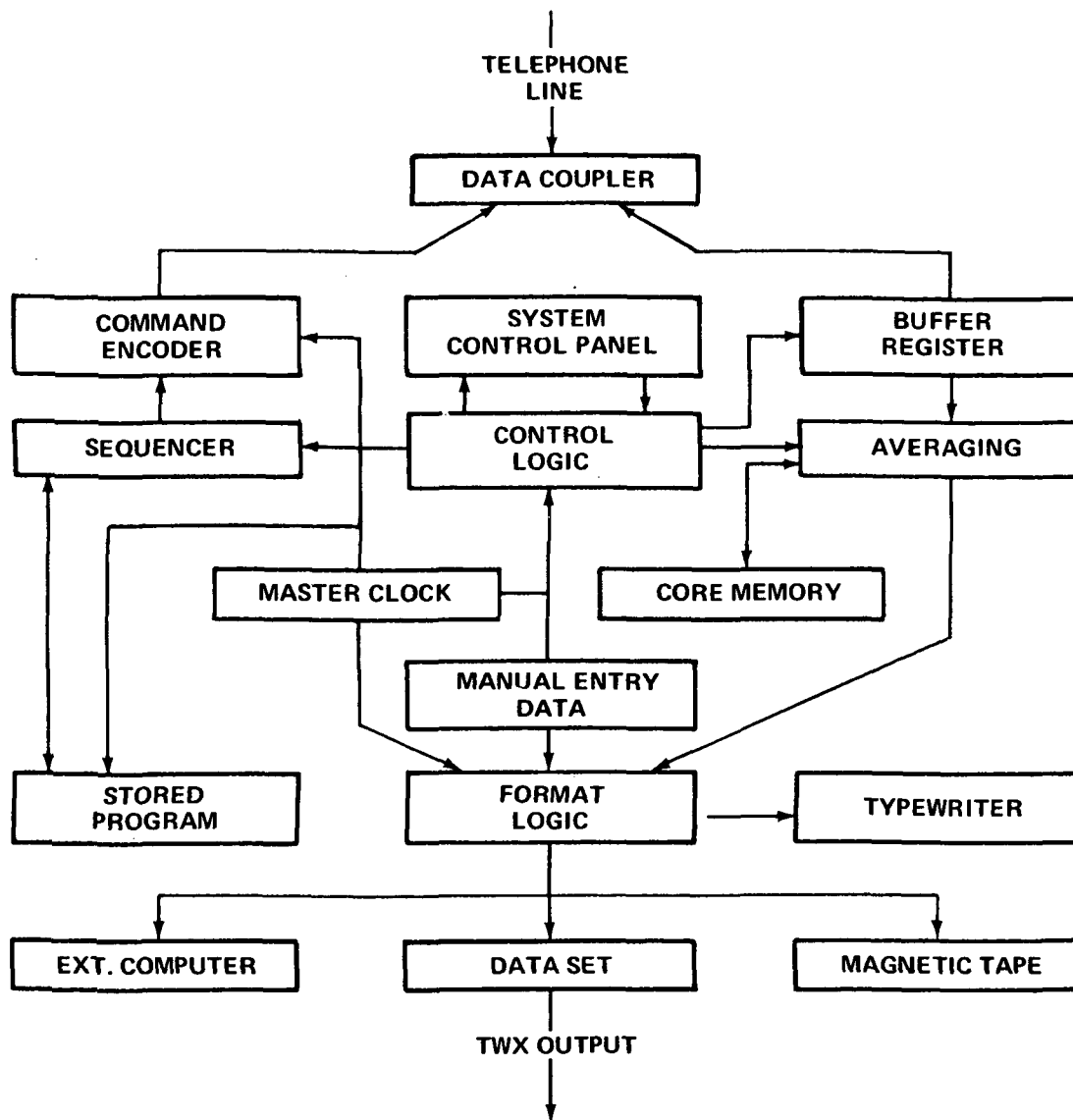


Figure 4.—Central station functions.

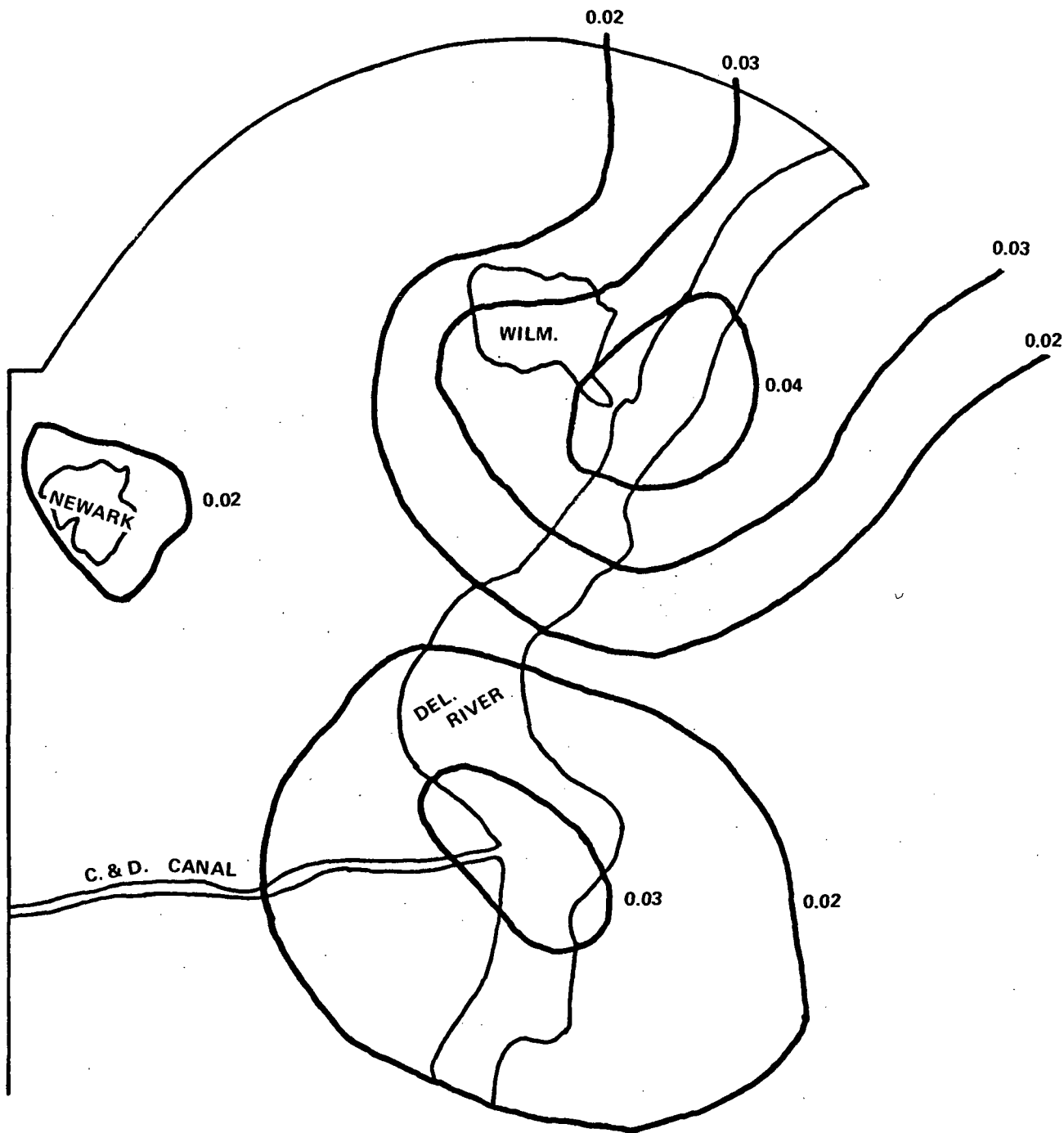


Figure 5.—Sulfur dioxide isopleth for New Castle County.

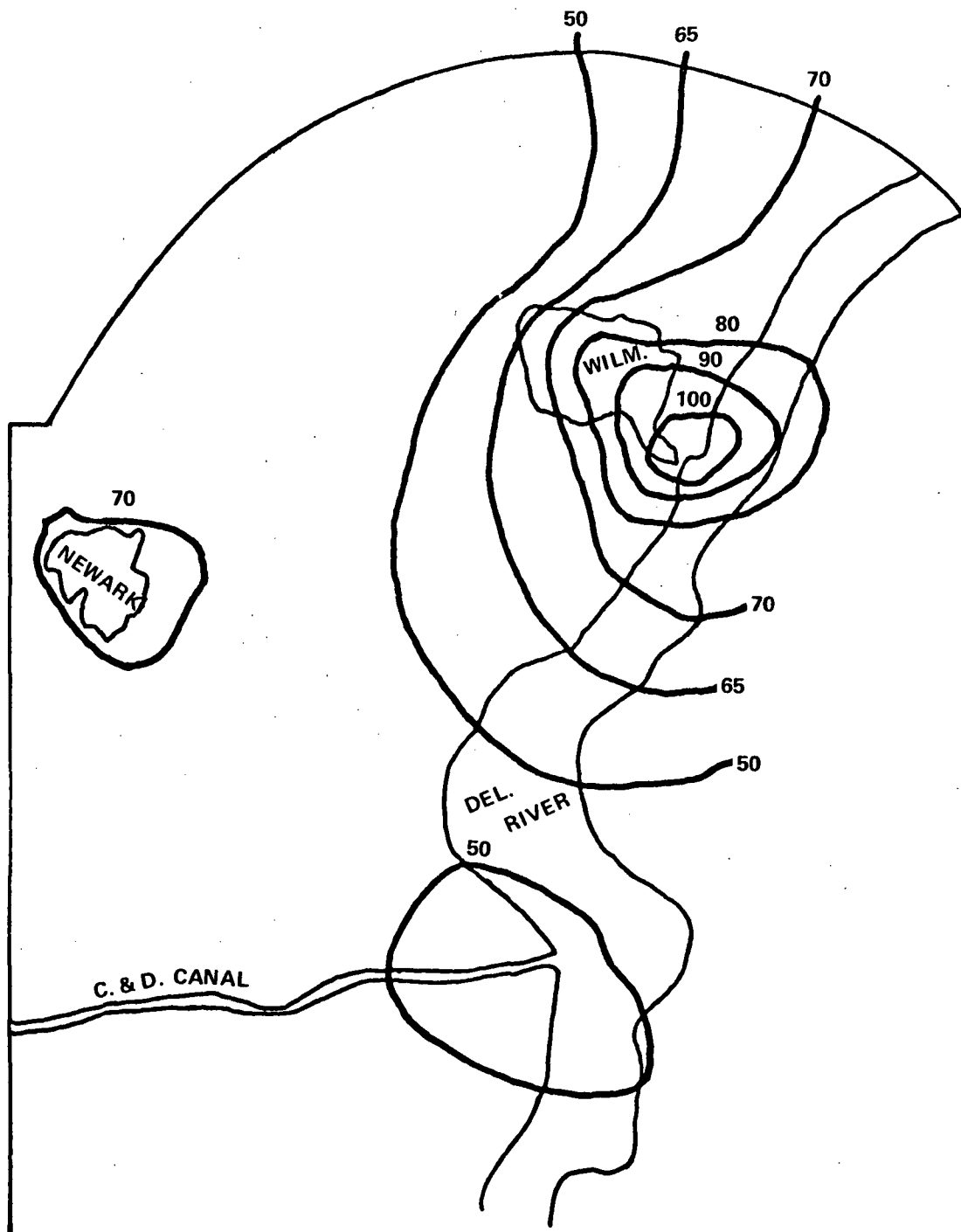


Figure 6.—Suspended particulate isopleth for New Castle County (geometric mean, $\mu\text{g}/\text{M}^3$).

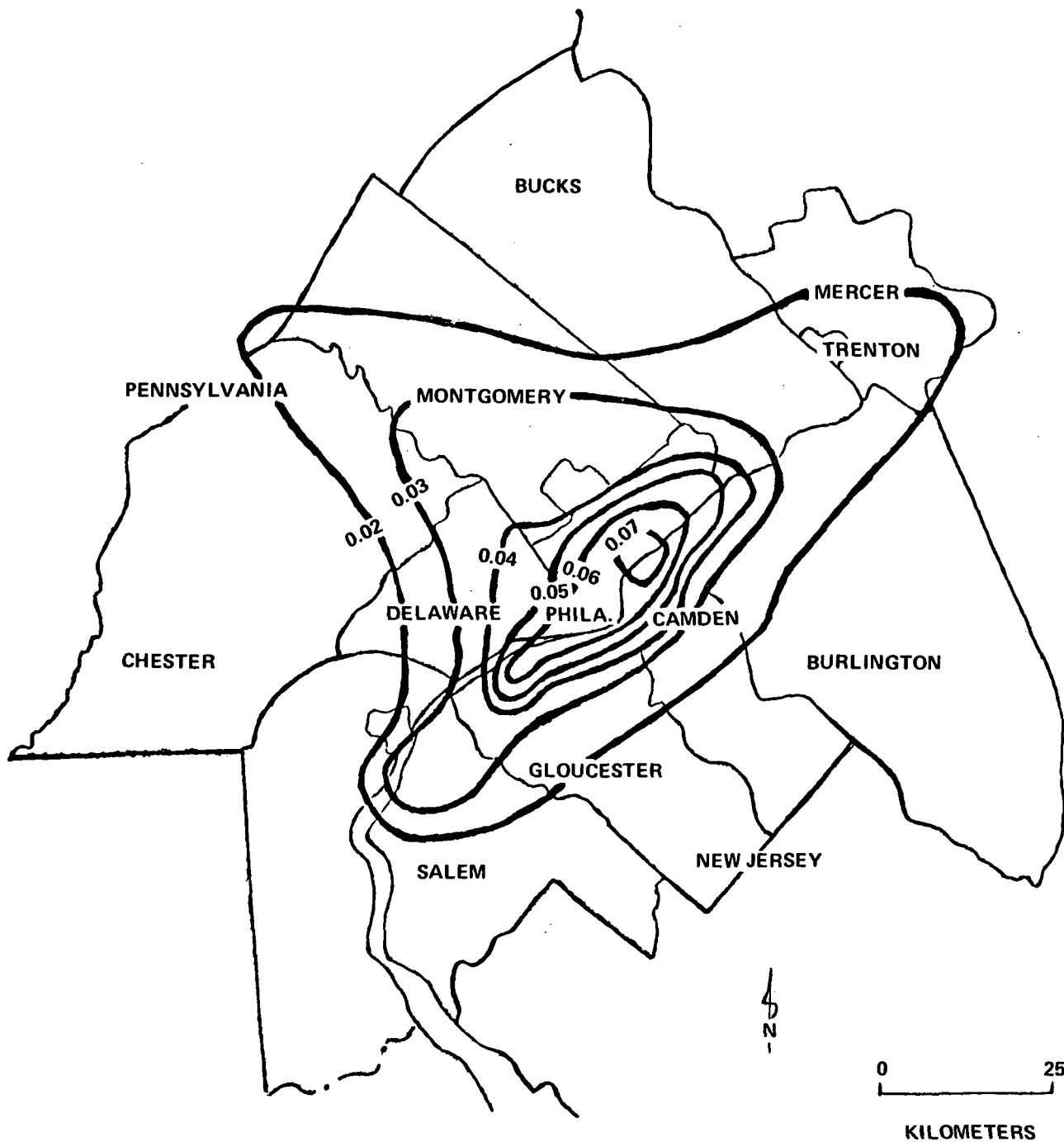


Figure 7.—Sulfur dioxide isopleth for the Philadelphia air-quality control region (arithmetic mean, ppm).

TABLE 3.—Contribution of Sulfur Oxide Emissions from Various Source Classifications

Source classification	Present emission (tons/year)	Proposed allowable emissions (tons/year)
Residential fuel burning	2100	2100
CIG fuel burning ^a	1200	800
Industrial fuel burning	29 000	13 800
Power generation	106 500	30 000
Industrial process	50 200	9600
Mobile	550	550
Total	189 550	56 850
Reduction of present emission levels		70%

^aCommercial, institutional and governmental (CIG).

TABLE 4.—Contribution of Particulate Emissions from Various Source Classifications

Source classification	Present emission (tons/year)	Proposed allowable emissions (tons/year)
Residential fuel burning	800	800
CIG fuel burning ^a	150	150
Industrial fuel burning	3600	^b 3600
Power generation	21 000	^c 1900
Industrial process	16 000	1400
Mobile	750	750
Total	42 300	8600
Reduction of present emission levels		80%

^aCommercial, institutional and governmental (CIG).

^bPossible reduction due to lower ash content of low sulfur fuel not indicated.

^cBased upon change from coal to oil that is dictated by Regulation IX.

provide a synoptic coverage which has never been possible with local sensors because the resources to install and operate such a vast network have never been, and in all probability, never will be available for that purpose.

A new family of remote sensing equipment based on optical methods and absorption characteristics are now becoming available. Barringer and Schock (ref. 7) cite a program of research to develop instrumentation which can detect a range of gases and vapors by optical methods with sensitivities in the parts-per-billion range. Their instrumentation technique is based on spectral absorption characteristics exhibited by many gases in the ultraviolet, visible and infrared portion of the spectrum. Jacobs and Snowman (ref. 8) suggest laser techniques for air pollution measurement based on the use of a carbon dioxide isotope laser working in the infrared band and a remote mirror. Yates (ref. 6) lists experiments already conducted by the Nimbus 4 series satellite wherein measurements have been made on temperature, water vapor mapping, atmospheric temperature profile, ozone, minor atmospheric gases, and changes in solar radiation.

Früangel (ref. 9) claims the use of a spark gap to generate ultraviolet pulses in the microsecond range which are transmitted to a receiver that notes changes induced by moisture droplets or impurities. Hanst and Morreal (ref. 10) describe the development of iodine infrared and carbon dioxide lasers which are forced to emit spectral lines which fall on the infrared absorption bands of atmospheric pollutants. Rendina and Grojean (ref. 11) explain the operation of a commercial electron impact spectrometer for high resolution analyses of gases and vapors.

Randerson (ref. 12) explains the use of photography from satellites for studying air pollution. Several photographs obtained during manned spacecraft flights illustrate opportunities for studying plume configuration and the extent of coverage.

The aforesaid indicate the interest developing in application of remote sensing to many environmental problems. We are very much interested in applying some of these techniques to obtain necessary information. Our specific needs in the Delaware Bay Region can be defined as follows:

- (1) Area-wide remote sensing is needed for indication of hot spots and pollution sources. For example, determination of the concentration of carbon monoxide at various locations would be of much value. Further, it is desirable to tag air masses so that the fate of this pollutant can be determined.

- (2) Plume characteristics must be determined to assess diffusion phenomenon. Three-dimensional measurements will assist considerably in refining dispersion models.

- (3) The prediction of inversions, the extent of pollutant buildup and the depth of the inversion layer may yield invaluable inputs for emergency episode planning.

- (4) The dispersion and lifecycles of radioactive materials released by nuclear power plants are of utmost concern for the well being of our citizens.

- (5) Remote sensing of vegetation may provide bases for assessing damage to crops and trees by air pollutants. Ground level surveillance can be improved using such information. Present techniques require constant movement of mobile monitors to follow the plumes and measure their ground effects.

- (6) The fate of pollutants in the atmosphere is of great value to air resources management programs. Information on the decay or chemical conversion of pollutants will help in improving our assessment capabilities.

This paper covered briefly the instrumental capabilities to monitor air quality at ground level and examined the role of remote sensing in the atmosphere. The need to relate both systems is urgent. We suggest that a program be developed in the Chesapeake and Delaware Bay areas to carry on the experimentation of remote sensing of the atmosphere.

The correlation of information with ground level systems, the development of prediction and warning systems, and the development of mathematical models would allow the manager of air resources in the broad area of the Chesapeake and Delaware Bays to anticipate problems before a crisis develops. Since such remote sensing capability can deal with more than one parameter—such as air—it may be more feasible to include water and land as a part of the complete environmental monitoring system. While we do not wish to appear chauvinistic, Delaware appears to be in a unique position because historical information is readily available on its water and air environment. This uniqueness extends to other areas, such as wildlife movement, and is expected to broaden in 1971 to include surveillance of biota of the total estuarine areas including marshlands.

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